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Environmental TEM in the *in situ* Toolbox

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Studies of materials using *in situ* techniques usually involve a compromise of the *in situ* conditions in order to fulfil the requirements compatible with the instrumentation for characterization. These requirements include sample geometry, temperature, gas environment etc.

Environmental TEM depends on complementary experiments and characterization techniques. Normally, this is done in parallel with experiments separated in time and space [1] or mimicking a reaction by changing the conditions according to e.g. reactivity and conversion measured in dedicated catalyst set-ups [2]. Furthermore, dedicated transfer holders have been used to transfer catalyst samples between reactor set-ups and TEM at room temperature in inert atmosphere [3].

To take the full advantage of the complementary *in situ* techniques transfer under reactions conditions is essential. Here we introduce the *in situ* transfer concept by use of a dedicated TEM transfer holder that is able to enclose the sample in a gaseous environment at temperatures up to approx. 900°C. The holder is compatible with other *in situ* technique set-ups.

Another route for using complementary techniques without compromising the sample conditions is bringing the techniques to the microscope. A dedicated custom TEM specimen holder containing two optical fibres, five electrical contacts, a fixed miniaturized optical bench for light handling and a heating element has been designed. A system of pre-aligned mirrors and a MEMS heater are implemented in the holder. The system is primarily designed for use in combination with LSPR spectroscopy [4], but it is flexible and can be employed with a variety of other methods that require light input and/or output. The two fibres can be used as parallel light inlets to activate a photoinduced reaction e.g. photoinduced reduction of particles [5]. Alternatively both fibres can be used to capture cathodoluminescence or other optical signals from the sample during electron irradiation.

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4. C. Langhammer et al. Nano Letters (2010) 3529
5. F. Cavalca et al. Nanotechnology (2012) 075705